

# *Strip intercropping productivity of maize and pulse crops on a dryland*

*I Komang Damar Jaya\*, Sudirman, Rosmilawati*

Faculty of Agriculture, University of Mataram

Jl. Majapahit 62 Mataram 83125 Lombok, West Nusa Tenggara - Indonesia

\*Email: ikdjaya@unram.ac.id

**Abstract-** Improving crop diversity on a piece of land, such as by intercropping, is one of the adaptation strategies in response to climate change in dryland areas. The aim of the present study was to estimate the strip intercropping productivity that was expressed as a Land Equivalent Ratio (LER) of maize and pulse crops on dryland. Two modern maize hybrid varieties, NK212 (non-premium) and NK7328 (premium), and two pulse crops, groundnut (*Hypoma-1*) and mungbean (*Vima-1*) were grown both as monoculture and strip intercropping. The study was conducted on an Entisol sandy soil area in a dryland sector of Gumantar village, North Lombok (8.253654 S, 116.285695 E). The size of each treatment plot was 8.4 x 5m with an east-west orientation. Maize crops were planted in double-rows with 35 x 20cm spacing within the row and 70cm between the double rows with one seed per hole. Groundnut and mungbean crops were planted at 20 x 20cm with one seed per hole. From these spacings, 70% of the land portion in strip intercropping was for maize and the other 30% was for either groundnut or mungbean. The results showed that the premium variety of maize NK7328 out-yielded NK212, both in monocrop and strip intercropping with mungbean and groundnut. All LER values for the strip intercropping were higher than 1.0, with the highest (1.25) from NK212-mungbean. These results indicate that strip intercropping of maize-pulse crops has a productivity advantage over monoculture on a dryland. In addition to higher productivity, strip intercropping can also spread the risk of crop failure in dryland areas during the recent period of high variability in climate.

**Keywords—** *adaptation, climate change, crop failure, diversity, productivity*

## I. INTRODUCTION

Climate change has resulted in an increase in air temperature and a change in rainfall patterns. Air temperature increases the impact on plant physiology activities and increases the intensity of pest attacks, plant diseases and weeds [1, 2]. Meanwhile, changes in rainfall patterns have an impact on the reduced availability of ground water [3]. The changes are relatively faster than the ability of plants to adjust [4]. As a result, food crop production has generally declined, particularly in South Asia and Africa [5]. This condition is exacerbated by the high rate of conversion of agricultural lands, while on the other hand, the need for food continues to increase as the world's population increases. Among the strategies that can be done to overcome the food problem are optimising the

utilisation of the land that is still less productive and to increase the diversity of the plants farmed.

The existence of unproductive lands such as a dryland is still quite wide; about 42.7% of the earth's surface area or an area of 6.15 billion hectares [6]. In Indonesia, especially in the Province of West Nusa Tenggara (NTB), the existence of less productive land is still quite widespread as well. Most of this less productive land is dryland; about 70% of the area of NTB, scattered in the northern parts south and east of the southern part of Lombok island and on most of the island of Sumbawa. This dryland has the potential to be developed into productive agricultural lands to meet the increasing national food needs. The problems of dryland in general are that the soil is poor in nutrient content and low in organic materials [6], thus requiring a high agricultural input to be able to produce optimally, as well as the occurrence of dry spells.

Among the food crops available, maize is the most grown crop by farmers in dryland areas. Maize is a farmer's first choice as it has a simple cultivation technique and the crop has a high market potential. Moreover, farmers have no difficulty in obtaining quality seeds because modern hybrid maize brands are available in the market. However, modern maize hybrids require high agricultural input, such as fertilizer if cultivated in drylands. Modern maize hybrid cultivation techniques are also not well understood by farmers and so their farming practices are the same as those for the local varieties. It is known that modern maize hybrid varieties have erect leaf morphology so that it can be grown at a high population density when in monoculture [7].

The high risk potential of total crop loss in monoculture is because the climate change effect requires farmers to spread the risk to other crops by increasing crop diversity. High crop diversity on a piece of land is also one of the strategies used to achieve sustainable agriculture through increasing the nutrient content and soil organic matter. Crop diversification on a piece of land can be done with some forms of intercropping. Intercropping, especially in relation to maize and pulse crops, is an old cultivation practice, but has recently been re-practiced in relation to the phenomenon of climate change. One form of intercropping that has been widely practiced is strip intercropping; which is to plant two or more plant species in narrow stripes on a stretch of land. To measure the productivity

of an intercropping, one of the ways is to calculate the land equivalency ratio (LER). LER can be calculated based on the following formula [8];  $LER = \sum(\frac{Yp_i}{Ym_i})$ , in which  $Yp$  and  $Ym$  are the yields of the plants grown in intercropping and monocropping, respectively. Ratio value ( $i$ ) is a part of the LER values, the values of which are summed in accordance to the number of component crops in an intercropping which will result in the value of LER itself. In addition to LER, the efficiency of business activities, such as the cost to revenue ratio (R / C ratio) of monoculture and strip intercropping can also be used as a measure of productivity. This research has studied the productivity of strip intercropping of modern maize hybrid varieties with pulse crops on a dryland.

## II. MATERIALS AND METHOD

A field experiment was conducted from August to November 2016 on a piece of dryland in Gumantar village, North Lombok (8.253654 S, 116.285695 E). The climate type in the experimental area according to the Oldeman classification was D type. The soil type was Entisol with a loam structure that has been categorised as being poor soil with 0.46% organic matter, 0.05% N total (Kejdhal), available P 11.25 ppm (Olsen) and exchangeable K 0.77 me%, pH 7.0 and field capacity of 29% (%/V). Since the experiments were conducted during a dry season, a deep-well pump was operated as the source of irrigation water. The irrigation was done by flooding the plots for approximately 15 minutes for every irrigation period and the irrigation occurred once a week until two weeks before the maize harvest.

The treatments were: (A) NK212 maize monoculture; (B) NK7328 maize monoculture; (C) Groundnut (var. Hypoma-1) monoculture; (D) Mungbean (var. Vima-1) monoculture; (E) Strip Intercropping maize NK212-groundnut; (F) Strip Intercropping maize NK212-mungbean; (G) Strip Intercropping maize NK7328-groundnut and (H) Strip Intercropping maize NK7328 -mungbean. The size of each treatment plot was 8.4 x 5m with an east-west orientation. Maize crops were planted as double-rows with 35 x 20cm spacing within the row and 70cm between the double rows with one seed per hole. Groundnut and mungbean (pulse crops) were planted at 20 x 20cm with one seed per hole. In these spacings, there were 8 pairs of double-row maize in monoculture and 6 pairs of double-row in strip intercropping, while for the pulse

crops, there were 44 and 10 rows for monoculture and strip intercropping, respectively. In terms of land use, the maize crops in the strip intercropping treatments occupied 70% and the pulse crops occupied 30% of the total land in each plot.

The maize crop was fertilised three times, namely at planting, at 35 days after planting (DAP) and 56 DAP. At the time of planting, Phonska N-P-K (15-15-15) fertiliser was applied at a rate of 300 kg ha<sup>-1</sup> along with Urea fertiliser at a rate of 100 kg ha<sup>-1</sup>. At 35 DAP, Phonska was reapplied at the same rate as at the planting time. The Urea fertiliser was reapplied at 56 DAP at a rate of 200 kg/ha. For the pulse crops, Urea fertiliser at a rate of 50 kg/ha and Phonska fertiliser at a rate of 125 kg/ha were given at planting and at 35 DAP. Before the application of the second fertilisers, hand weeding was done in all of the experimental plots. No pest problems were observed during the experiment.

The variables measured for maize yield and its components were the length of cob, cob diameter, grain weight per cob, percentage of grain weight to cob weight, weight of 1000 grains and seed weight per plot. Meanwhile, the yield of the pulse crops observed was by seed weight per plot which then was converted to hectare for Land Equivalent Ratio (LER) calculation as a productivity indicator. For the economic efficiency of all of the cultural practices tested, the ratio of cost to revenue (R/C ratio) was calculated. The data on the yield components of the maize crop was analysed using Analysis of Variance.

## III. RESULTS AND DISCUSSION

No significant differences ( $P > 0.05$ ) were found in the components of the maize yields, including length of cobs, cob diameter, grain weight per cob, percent weight of grain to cob and weight of 1000 grains between the modern maize hybrid varieties tested, both in monoculture and strip intercropping (Table 1). In general, the premium varieties of NK7328 had a dry grain weight per cob and weight of 1000 grains about 7% and 9%, respectively higher than the NK212 variety. Such conditions have the potential to affect crop yields per unit area of land. The absence of a significant difference from the yield components variable statistically was caused by the high variation of data obtained so that the  $R^2$  value of the data relation with the model used was relatively low ( $R^2 < 60\%$ ).

TABLE 1. Yield components of NK212 and NK7328 varieties of maize crops grown in monoculture and strip intercropping with groundnut varieties Hypoma-1 and mungbean of varieties Vima-1

Treatments	Maize yield components				
	Cob length (cm)	Cob diameter (mm)	Grains dry weight (g/cob)	% grains to cob	Weight of 1000 grains (g)
NK212 Monoculture	15.63	39.47	121.80	70.12	306.33
NK7328 Monoculture	15.93	40.07	135.73	78.44	332.33
NK212-Hypoma-1	15.55	39.94	136.00	80.54	306.33
NK212-Vima-1	16.63	40.68	141.53	77.38	326.33
NK7328-Hypoma-1	15.82	37.80	133.67	81.26	290.00
NK7328-Vima-1	16.19	41.03	141.80	79.37	324.00
<i>P</i> value	0.392	0.659	0.633	0.636	0.074
$R^2$ (%)	39.48	41.70	55.76	55.95	59.14

The maize hybrid of the premium varieties NK7328 produced a higher yield ( $\pm 20\%$ ) than the non-premium NK212, both in monoculture and in strip intercropping (Table 2). This fact indicates that the NK7328 maize hybrid does have a higher yield potential than that of NK212, so it is categorised as a premium variety with a seed selling price about 30% higher than the NK212 seeds. The higher yield of NK7328 compared to NK212 resulted in an economic efficiency (R / C ratio) of growing NK7327 maize that was higher by 19% compared to NK212 in monoculture (Table 2). In this table, it can also be seen that NK7328 had a higher R / C ratio than NK212 in strip intercropping, either with groundnut or with mungbean. The cultivation of crops that produced the highest economic efficiency in the dryland of North Lombok was to grow groundnut Hypoma-1 in monoculture. However, due to a limited market capacity for the peanut, farmers in the dryland areas of North Lombok are not advised to cultivate all of their land with groundnut and mungbean. The diversification of crops by planting NK7328 maize with groundnut Hypoma-1 in addition to having a high R / C ratio (4.26) can also be used as an adaptation strategy to climate change since groundnut is a relatively drought resistant crop.

Strip intercropping of modern maize hybrid varieties in this study had a higher productivity than in monoculture. This can

be seen from the LER values of all of the treatments in strip intercropping which were  $> 1$  (Table 2), which means that the land use efficiency is higher in strip intercropping compared to the monoculture system [8]. This result is in accordance with an earlier finding that stated that strip intercropping was more productive than monoculture [9]. Strip intercropping of NK212, either with groundnut or with mungbean, always produced higher LER values than that of NK7328. This result indicates that the maize hybrid variety of NK212 will be more productive than NK7328 when grown in strip intercropping, especially with mungbean on drylands. The LER value of 1.25 for strip intercropping of NK212 with mungbean means that the area used to plant NK212 in monoculture would require 25% more land to produce the same yield as the same area planted in strip intercropping. The strip intercropping of NK212 maize with mungbean on dryland, in addition to having high productivity, also has the potential to be developed as one of the adaptation strategies to climate change due to the short growing period of mungbean ( $\pm 56$  days). Both maize varieties have a growing period of more than 100 days. With these differences in growing period among the component crops in strip intercropping, the risk of maize crop failure due to climate variability can be spread into other crops, such as mungbean. When a dry spell causes loss in maize, dryland farmers will still be able to harvest mungbean or groundnut.

TABLE 2. Yield of all component crops, land equivalent ratio (LER) and cost to revenue ratio (R/C) of all treatments

Treatments	Maize yield (ton ha <sup>-1</sup> )	Groundnut yield (ton ha <sup>-1</sup> )	Mungbean yield (ton ha <sup>-1</sup> )	LER	R/C
<i>Monoculture</i>	a)				
Maize NK212	6.35 b	-	-	-	2.38
Maize NK7328	7.97 a	-	-	-	2.84
Groundnut Hypoma-1	-	2.14	-	-	12.56
Mungbean Vima-1	-	-	1.19	-	4.05
<i>Strip Intercropping</i>					
NK212-Hypoma-1	5.83 d	0.59	-	1.22	3.94
NK212-Vima-1	5.83 d	-	0.39	1.25	2.64
NK7328-Hypoma-1	63.5 b	0.64	-	1.10	4.26
NK7328-Vima-1	6.19 c	-	0.41	1.10	3.02

a) Values followed by different letter in Maize yield column are significantly different at 5% level by Tukey test

#### IV. CONCLUSIONS

The modern maize hybrid variety of NK7328 produced a 20% higher yield than NK212 when grown in monoculture on dryland. Both varieties are more productive when they were grown in strip intercropping with pulse crops, such as groundnut and mungbean, than when they were grown as monoculture. In strip intercropping, NK212 has a 12% higher productivity than NK7328, as indicated by the higher LER values, especially in strip intercropping with mungbean. These results indicate that the strip intercropping of modern maize hybrid variety of NK212 with mungbean Vima-1 has a higher productivity and economic efficiency, and therefore is a good option to be developed as an adaptation strategy to climate change in dryland areas.

#### *Acknowledgment*

The study was part of the Applied Research and Innovation Systems in Agriculture (ARISA) Dual Cropping Project (2016-2018) funded by the Department of Foreign Affairs and Trade (DFAT) Australia contracted to the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

## References

1. A.S. Jump and J. Peñuelas. "Running to stand still: adaptation and the response of the plants to rapid climate change". *Ecol Lett*, vol. 8, pp 1010-1020, 2005.
2. D.I. Gustafson. "Climate change: a crop protection challenge for the twenty-first century". *Pest Manag Sci*, vol. 67, pp 691-696, 2011.
3. E. Pugano and G.A. Maddoni. "Intra-specific competition in maize: Early establishment hierarchies differ in plant growth and biomass partitioning to ear around silking". *Field Crops Res.*, vol. 101, pp 306-320, 2007.
4. L.H. Ziska. "The impact of elevated CO<sub>2</sub> on yield loss from a C3 and C4 weed in field-grown soybean". *Glob Chang Biol*, vol. 6, pp 899-905, 2000.
5. L. Li, J. Sun, F. Zhang, X. Li, S. Yang and Z. Rengel. "Wheat/maize or wheat/soybean strip intercropping I. Yield advantage and interspecific interactions on nutrients". *Field Crops Res*, vol. 71, pp 123-137, 2001.
6. M. Dariush, M. Ahad, O. Meysam. "Assessing the land equivalent ratio (LER) of two corn (*Zea mays* L.) varieties intercropping at various nitrogen levels in Karaj, Iran". *J Cen Eur Agr*, vol. 7, pp 359-364, 2006.
7. M. Parry, C. Rozenweig and M. Livermore. "Climate change, global food supply and risk of hunger". *Phil. Trans. Roy. Soc. B. Biol. Sci.*, vol. 360, pp 2125-2138, 2011.
8. N. Kalra, S. Chandler, H. Pathak, P. K. Aggarwal, N. C. Gupta, M. Sehgal and D. Chakraborty. "Impacts of climate change on agriculture". *Outlook Agric*, vol. 36, pp 109-118, 2007.
9. R. Lal. "Carbon sequestration in dryland ecosystems". *Environ Manage*, vol. 33, pp 528-544, 2004.